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NASA PROGRAM GEMINI WORKING PAPER NO. 5042

INSTRUMENTATION AND ELECTRONIC SYSTEMS IMPLEMENTATION FOR GEMINI PARASAIL RETROROCKET SYSTEM

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

MANNED SPACECRAFT CENTER

HOUSTON, TEXAS

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INSTRUMENTATION AND ELECTRONIC SYSTEMS IMPLEMENTATION FOR GEMINI PARASAIL RETROROCKET SYSTEM

Prepared by: Field Test Instrumentation Section

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By Field Test Instrumentation Section

INTRODUCTION

The Instrumentation and Electronic Systems Division (IESD) has provided the instrumentation for a program to evaluate the performance of the Parasail-type parachute and its application to a Gemini earth landing. This was done in support of the Landing Technology Branch of the Structures and Mechanics Division (S&MD), who initiated and directed the program. Instrumentation was provided to measure the loads and aerodynamic parameters of these Parasail parachutes and the boilerplate Gemini capsules. The impact loads, retrorocket system, and landing gear performance were monitored.

Three distinct instrumentation systems were used on two Gemini boilerplate spacecrafts (BP-205 and BP-206). The first system (fig. 16) was designed to provide load data on the Parasail parachute. This system was used for air drop number 1 and consisted of seven measurements (table I) with an onboard recording system. The second system (fig. 17) was used on air drops 2 through 5. It consisted of 31 measurements (table II), telemetry, and command systems. The third and final system (fig. 18) was designed and used on air drops 6 through 12. It consisted of 43 measurements (table III) which were added to handle the additional measurement requirements of the retrorocket subsystem.

These systems were designed, fabricated, and calibrated in a joint effort by all branches of the IESD. The following is a list of each branch and their responsibilities:

General Instrumentation	–	Overall systems responsibility, instrumentation, power, and signal distribution.
Flight Data Systems	–	Onboard telemetry systems, telemetry ground station, and A-D conversions.

Standards and Quality Assurance	– Calibration and inspection.
Electromagnetic Systems	– Telemetry transmitters, command system, and all antenna systems.

MEASUREMENT CHANGES, PROBLEMS, AND TECHNIQUES

Signal Conditioning

The signal conditioning used to amplify the low signal level transducers for air drops 2 through 5 was Statham carrier amplifiers (Model CA17-64). These amplifiers were found to be unacceptable for this type of test because the drift in the output circuit that was observed from the final instrument checkout to the air drop was too great. Drifts were found to be as great as 8 percent of full scale. The time between the final instrument checkout and air drop was about 30 hours. The Gulton dc amplifier (Model EM2000 D2) was incorporated on air drops 6 through 12 and this drift problem was corrected.

Control Line Load Measurements

The load links which were used for these measurements on air drops 2 through 6 were found not to be compatible with this test article. This first configuration was a small strain-gaged load link which was inserted into the control line between the turn control motor and the parachute. These links were designed for 250 pounds. Because these links and their connecting cables had to be placed in the control line outside the boilerplate, problems were experienced during deployment. The connecting cables were tangled in the control lines during this deployment because proper storage could not be made on the boilerplate. This problem was solved by designing and fabricating a load-measuring device which could be placed on the inside of the boilerplate (see fig. 4). This device was placed between the turn-control motors and their exits inside the boilerplate, thereby eliminating the external sensor and cable.

Chamber Pressure Measurement P-42 and P-44

Preliminary tests were made on the retrorocket motor prior to flight tests. During these tests the chamber pressure of these motors was monitored. The normal chamber pressure which was expected was approximately 3100 psi with a peak pressure of 3500 psi. For the best resolution a CEC Model 4-326 unbonded strain gage transducer was selected (0 to 3500 psig range). Following the first test, an analysis of the data revealed a large zero shift at the end of the data run. It was also noted that a rather large pressure transient existed at the rocket ignition. On the next static firing 0 to 10,000 psi transducers were used, and this transient was found to be 7,100 psi and existed for about 4 milliseconds. This time was the upper limit of the frequency response of the transducers. The upper limit of the frequency response was required of the transducer in order to define the transient condition. Procurement was made on 0 to 5000 psi transducers which had a two-times-overload capability. These transducers functioned properly, for no other shifts were noted and data was considered reliable on all flights.

Attitude Gyro

An adequate pitch-angular-attitude measurement was never made because a reliable gyro could not be obtained which would withstand the environment of this test. Some data was taken with a Giannini Model 3416DV.06, but because its range was continually exceeded during attitude change, its reference was lost and the data was considered unsatisfactory thereafter.

Angle of Attack

Although an angle-of-attack measurement was not made, this measurement would have added considerably to the aerodynamic characteristics data which were gathered. Considerable effort was made to acquire an instrument to make this measurement but an accurate one (10 to 40 ft/sec) could not be found that would be applicable to the environment of these tests or that could be physically located on the test boilerplates. A good low-velocity angle-of-attack measuring device is needed.

Batteries

Because of economy and the availability of equipment, four Eagle Picher Model MAR-8000 (5 ampere hour) batteries were used to power all instrumentation electronic systems. These were nickel-cadmium batteries and could be readily recharged following each sequence test or air drop. Problems were encountered during the first three drops because of a low resistance to ground that was noticed following the completion of each drop. This low resistance was due to leakage caused by broken cells within the battery. Ground tests were made an it was found that after the recharging of the battery, the vent caps were replaced tightly too soon, resulting in a residual pressure build-up within each cell. The batteries were then installed on the boilerplate and when the boilerplate was carried to the drop altitude of 11,000 feet, the outside pressure decreased, therefore the differential pressure was greater than 40 psi and several of the cells' seals burst. The vent valves on these batteries apparently failed. The water from these cells leaked out and the low-resistance short occurred; however, this short was never great enough to cause a power failure. This problem was eliminated by venting each cell at least 12 hours each time the battery was recharged. The vent caps were secured just prior to their installation in the spacecraft, which was about 6 to 8 hours before the drop. No further shorts were observed following this operation.

Ground Receiving Station

When this program was initiated in October 1963, a ground telemetry receiving station was required which could be readily moved from the ground checkout station to the drop site. The drop sites were Trinity Bay and Fort Hood, Texas. The Telemetry Receivings Techniques Section, IESD, provided two telemetry receivers and six discriminators. A number of real-time data channels were required so that the test conductor would have the necessary information to intelligently control the Parasail. The control line positions and loads were monitored real time. Additional real-time channels were needed, but equipment was not available and funds were also not available.

Launch release time.- All of the sequence times which were on the spacecrafts were initiated from launch release. This time was accurately recorded but had to be placed on a commutated channel because of the number of high-frequency measurements required which had to be placed on the straight telemetry channels. This is an important measurement that should have been recorded real time. This would have enabled the test conductor to receive an accurate time of launch release so that corrective action could be taken if other events did not occur at predetermined times. These real-time requirements were handled by voice communication with the drop aircraft (C-119) and a ground communicator who started a timer.

Rocket arm (lockouts 1 and 2).- In addition to the launch release time, two other important real-time measurements were needed. These were the events which indicated that each rocket motor was armed and that the altitude sensor had been deployed. Knowledge of this event was important on the earth-landing tests because if these motors were not armed, the landing gears would not be deployed. Damage would be incurred to the landing gear if the motors were not fired. This measurement was also placed on a commutated channel. Real-time readouts were made by displaying the PAM wave train on an oscilloscope and these events were visually monitored. This is a difficult task and a great deal of error can be introduced.

Antenna Systems

A signal was required from the boilerplate to the ground station for the primary and secondary commands, and telemetry during the time when the spacecraft was in the drop aircraft, in all attitudes of flight, and after impact in the water. The command systems antennas were designed in order to provide linear polarization on the spacecraft and circular polarization omnidirectional coverage on the ground. The initial TM antenna system that was installed was a slot type. This was found to be incompatible because following the spacecraft impact, the jar would de-tune the capacitive-tuned slot and result in a loss of signal. This type was replaced by a $\frac{1}{4}$-wave whip antenna. Three whip antennas were fed in phase, two of which were mounted diametrically opposite near the vehicle base, and one mounted between the hatches. This arrangement was used for the primary command and telemetry antennas. The secondary command systems antenna consisted of two whip antennas which were fed in phase diametrically opposite and mounted on the base of the vehicle. No problems were encountered with this system.

On air drops 5 through 12 the antennas mounted on the spacecraft had to be moved because of the location of the retrorocket motors. They were then mounted such that they were diametrically opposite the hatches rather than the vehicle base. The television antennas were also mounted at this time.

CALIBRATIONS

All sensors were calibrated by the IESD calibration laboratory. These calibrations were made with certified standards and were calibrated prior to each test. The auxiliary test equipment – oscilloscopes, digital voltmeters, counters, et cetera – were also calibrated and certified by this laboratory.

DATA HANDLING

Following the calibration of each measurement, the calibration data was forwarded to the Computation and Analysis Division (C&AD), where it was placed within the computer program for each test. Normally, the calibration data did not change except when new transducers or requirements were made. Each air drop was recorded on magnetic tape. This data was received from two telemetry receivers. The data was sent through discriminators and then digitized by the Telemetry Receiving Techniques Section, IESD, and given to the C&AD. At the C&AD the data were tabulated and plotted as requested by the S&MD and IESD. The Telemetry Receiving Techniques Section also made an analog oscillograph record of each measurement. These were primarily made for quick-look data trends and failure analysis. (See data flow chart, fig. 5.)

MEASUREMENT LIST FORMAT AND NOMENCLATURE

The measurement requirement list consists of all flight parameters. These parameters are grouped by functional spacecraft systems to aid in system evaluation. The format and nomenclature are as follows:

A acceleration

B positions or strokes

E events

F force

O attitude

P pressures

R rates

T temperature

V voltage

TABLE I.- MEASUREMENT REQUIREMENTS – AIR DROP 1

Measurement number	Measurement description	Range	Xdcr make	Xdcr model	Frequency response	Recording	
						Mode	Channel
A-27	Impact acceleration Y-axis	±15g's	Statham	AJ15-15-350	135 cps	Oscillograph	6
F-11	Combined riser load	0 to 20 K lb	MSC		135 cps	Oscillograph	1
F-12	Front riser load	0 to 5 K lb	MSC		135 cps	Oscillograph	2
F-13	Middle riser load	0 to 5 K lb	MSC		135 cps	Oscillograph	3
F-14	Right aft riser load	0 to 5 K lb	MSC		135 cps	Oscillograph	4
F-15	Left aft riser load	0 to 5 K lb	MSC		135 cps	Oscillograph	5
P-32	Rate of descent	0 to 15 psia	CEC	4-328-0002	135 cps	Oscillograph	7

TABLE II.- MEASUREMENT REQUIREMENTS – AIR DROPS 2 THROUGH 5

Measurement number	Measurement description	Range	Xdcr make	Xdcr model	Frequency response	Recording	
						Mode	Channel
A-24	Linear acceleration Y-axis	±2g's	Statham	AJ17-2-350	10 sps	PAM	27
A-25	Linear acceleration X-axis	$\pm\frac{1}{2}$g	Statham	A4-0.5-350	10 sps	PAM	28
A-26	Linear acceleration Z-axis	$\pm\frac{1}{2}$g	Statham	A4-0.5-350	10 sps	PAM	29
A-27	Impact acceleration Y-axis	±15g's	Statham	AJ15-15-350	330 cps	VCO	14
A-28	Impact acceleration X-axis	±10g's	Statham	A69 TC-10-350	110 cps	VCO	11
A-29	Impact acceleration Z-axis	±10g's	Statham	A69 TC-10-350	160 cps	VCO	12
A-54	Angular acceleration pitch axis	100 RAD/sec^2	Statham	AA20-100-350	220 cps	VCO	13
D-22	Left control line position	0 to 2 ft	Pot (spectrol)		14 cps	VCO	5
D-23	Right control line position	0 to 2 ft	Pot (spectrol)		20 cps	VCO	6
E-59	Launch release				10 sps	PAM	31
E-60	R and R can separation				10 sps	PAM	32
E-61	Attitude change				10 sps	PAM	57
E-65	Backup parachute activation				10 sps	PAM	59
E-66	Left turn command (unwind)				10 sps	PAM	73
E-67	Right turn command (unwind)				10 sps	PAM	76
E-69	Left turn command (wind)				10 sps	PAM	74
E-70	Right turn command (wind)				10 sps	PAM	75

TABLE II.- MEASUREMENT REQUIREMENTS – AIR DROPS 2 THROUGH 5 - Concluded

Measurement number	Measurement description	Range	Xdcr make	Xdcr model	Frequency response	Recording	
						Mode	Channel
F-11	Combined riser load	0 to 20 K lb	MSC		80 cps	VCO	10
F-12	Front riser load	0 to 5 K lb	MSC		60 cps	PAM	3, 18, 33, 48, 63, 78
F-13	Middle riser load	0 to 5.0 K lb	MSC		60 sps	PAM	4, 19, 34, 49, 64, 79
F-14	Left aft riser load	0 to 5.0 K lb	MSC		60 sps	PAM	5, 20, 35, 50, 65, 80
F-15	Right aft riser load	0 to 5.0 K lb	MSC		60 sps	PAM	6, 21, 36, 51, 66, 81
F-16	Left control line load	0 to 100 lb	MSC		6 cps	VCO	2
F-17	Right control line load	0 to 100 lb	MSC		8 cps	VCO	3
0-21	Pitch attitude	0 to 360 deg	Giannini	3416-0V.06	11 cps	VCO	4
0-68	Inner gimbal	0 to 360 deg	Diannini	3416-0V.06	10 sps	PAM	61
P-32	Rate of descent	0 to 15 psia	CEC	4-328-0002	10 sps	PAM	47
R-18	Yaw rate	±180 deg/sec	Humphrey	RG01-1601-1	10 sps	PAM	13
R-20	Pitch rate	±120 deg/sec	Humphrey	RG01-2601-1	10 sps	PAM	15
T-46	Ambient temperature	20 to 60° C	Trans-Sonic	T4082A-4	10 sps	PAM	16
V-53	Power distribution	0 to 32 V dc	MSC		10 sps	PAM	30

TABLE III.- MEASUREMENT REQUIREMENTS - AIR DROPS 6 THROUGH 12

Measurement number	Measurement description	Range	Xdcr make	Xdcr model	Frequency response	Recording	
						Mode	Channel
A-24	Linear acceleration Y axis	±2g's	Statham	AJ17-2-350	10 sps	PAM	27
A-25	Linear acceleration X-axis	±1g	CEC	4-205	10 sps	PAM	28
A-26	Linear acceleration Z-axis	±1g	CEC	4-205	10 sps	PAM	29
A-27	Impact acceleration Y-axis	±15g's	CEC	4-202	330 cps	VCO	14
A-28	Impact acceleration X-axis	±10g's	CEC	4-202	110 cps	VCO	11
A-29	Impact acceleration Z-axis	±10g's	CEC	4-202	160 cps	VCO	12
A-31	Thrust acceleration Y-axis	±10g's	CEC	4-202	450 cps	VCO	15
A-33	Footwell acceleration Z-axis	±10g's	CEC	4-202	35 cps	VCO	7
A-34	Footwell acceleration X-axis	±10g's	CEC	4-202	45 cps	VCO	8
A-35	Footwell acceleration Y-axis	±10g's	CEC	4-202	59 cps	VCO	9
A-54	Angular acceleration pitch axis	100 RAD/sec^2	Statham	AA20-100-350	220 cps	VCO	13
D-22	Left control line position	0 to 42 in.	Pot		14 cps	VCO	5
D-23	Right control line position	0 to 42 in.	Pot		20 cps	VCO	6
E-47	Altitude sensor arm				10 sps	PAM	43
E-48	Altitude sensor lockout no. 1				10 sps	PAM	44
E-59	Launch release				10 sps	PAM	31
E-60	R and R can separation				10 sps	PAM	32
E-61	Attitude change				10 sps	PAM	57

TABLE III.- MEASUREMENT REQUIREMENTS – AIR DROPS 6 THROUGH 12 - Continued

Measurement number	Measurement description	Range	Xdcr make	Xdcr model	Frequency response	Recording	
						Mode	Channel
E-62	Landing gear deployment				10 sps	PAM	87
E-63	Blast deflector release				10 sps	PAM	58
E-64	Rocket fire				10 sps	PAM	88
E-65	Backup parachute activation				10 sps	PAM	59
E-66	Left turn command (unwind)				10 sps	PAM	73
E-67	Right turn command (unwind)				10 sps	PAM	76
E-69	Left turn command (wind)				10 sps	PAM	74
E-70	Right turn command (wind)				10 sps	PAM	77
F-11	Combined riser load	0 to 20 K lb	MSC		80 cps	VCO	10
F-12	Front riser load	0 to 5 K lb	MSC		60 sps	PAM	3, 18, 33, 48, 63, 78
F-13	Middle riser load	0 to 5 K lb	MSC		60 sps	PAM	4, 19, 34, 49, 64, 79
F-14	Left aft riser load	0 to 5 K lb	MSC		60 sps	PAM	5, 20, 35, 50, 65, 80
F-15	Right aft riser load	0 to 5 K lb	MSC		60 sps	PAM	6, 21, 36, 51, 66, 81
F-16	Left control line load	0 to 125 lb	MSC		6 cps	VCO	2
F-17	Right control line load	0 to 125 lb	MSC		8 cps	VCO	3
0-21	Pitch angular attitude	0 to 360 deg	Giannini	3416-DV.06	10 cps	VCO	4
0-68	Inner gimbal	0 to 360 deg	Giannini	3416-DV.06	10 sps	PAM	61

TABLE III.- MEASUREMENT REQUIREMENTS – AIR DROPS 6 THROUGH 12 - Concluded

Measurement number	Measurement description	Range	Xdcr make	Xdcr model	Frequency response	Recording	
						Mode	Channel
P-32	Rate of descent	0 to 15 psia	CEC	4-328	10 sps	PAM	47
P-42	Rocket chamber pressure, left	0 to 5000 psia	CEC	4-326 Special	790 cps	VCO	17
P-44	Rocket chamber pressure, right	0 to 5000 psia	CEC	4-326 Special	600 cps	VCO	16
R-18	Angular rate, yaw	±30 deg/sec	Humphrey	RG02-2320-1	10 sps	PAM	13
R-19	Angular rate, roll	±120 deg/sec	Humphrey	RG02-2320-1	10 sps	PAM	14
R-20	Angular rate, pitch	±120 deg/sec	Humphrey	RG02-2320-1	10 sps	PAM	15
T-46	Ambient temperature	20 to 60° C	Trans-Sonic	T4082A-4	10 sps	PAM	16
V-53	Power distribution – voltage	0 to 32 V dc			10 sps	PAM	30

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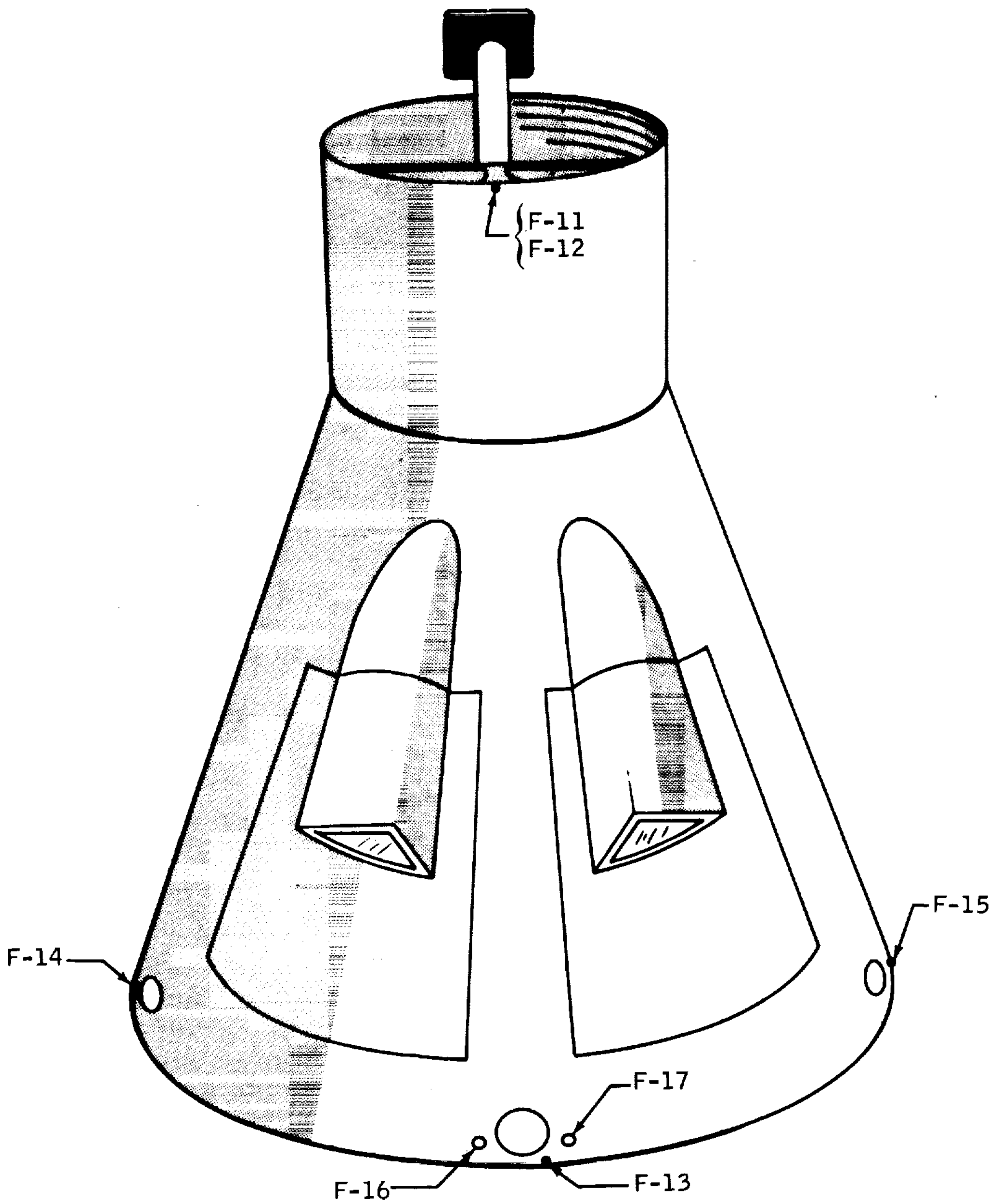

Figure 1. - Measurement locations - top view

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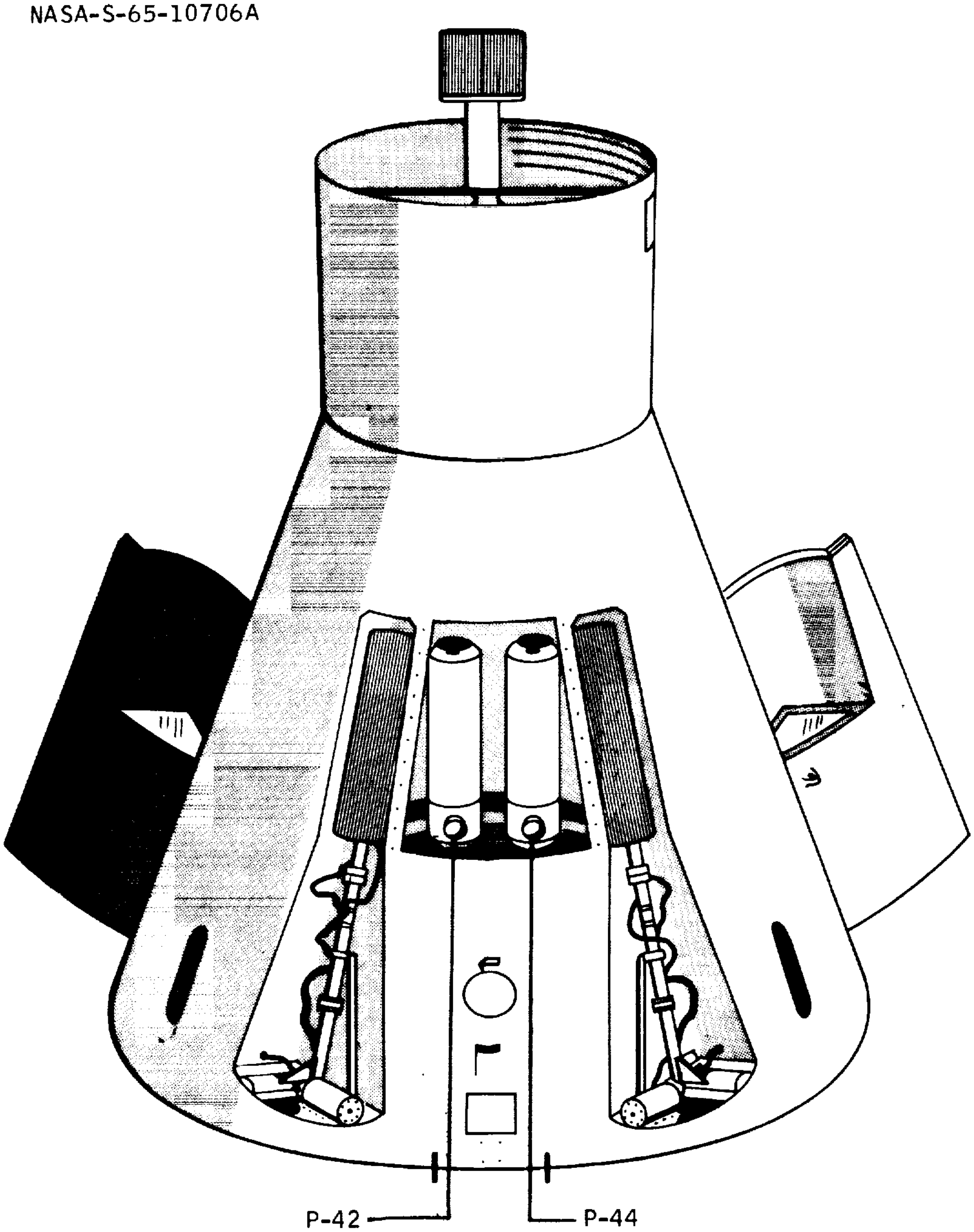

Figure 2. - Measurement locations - bottom view

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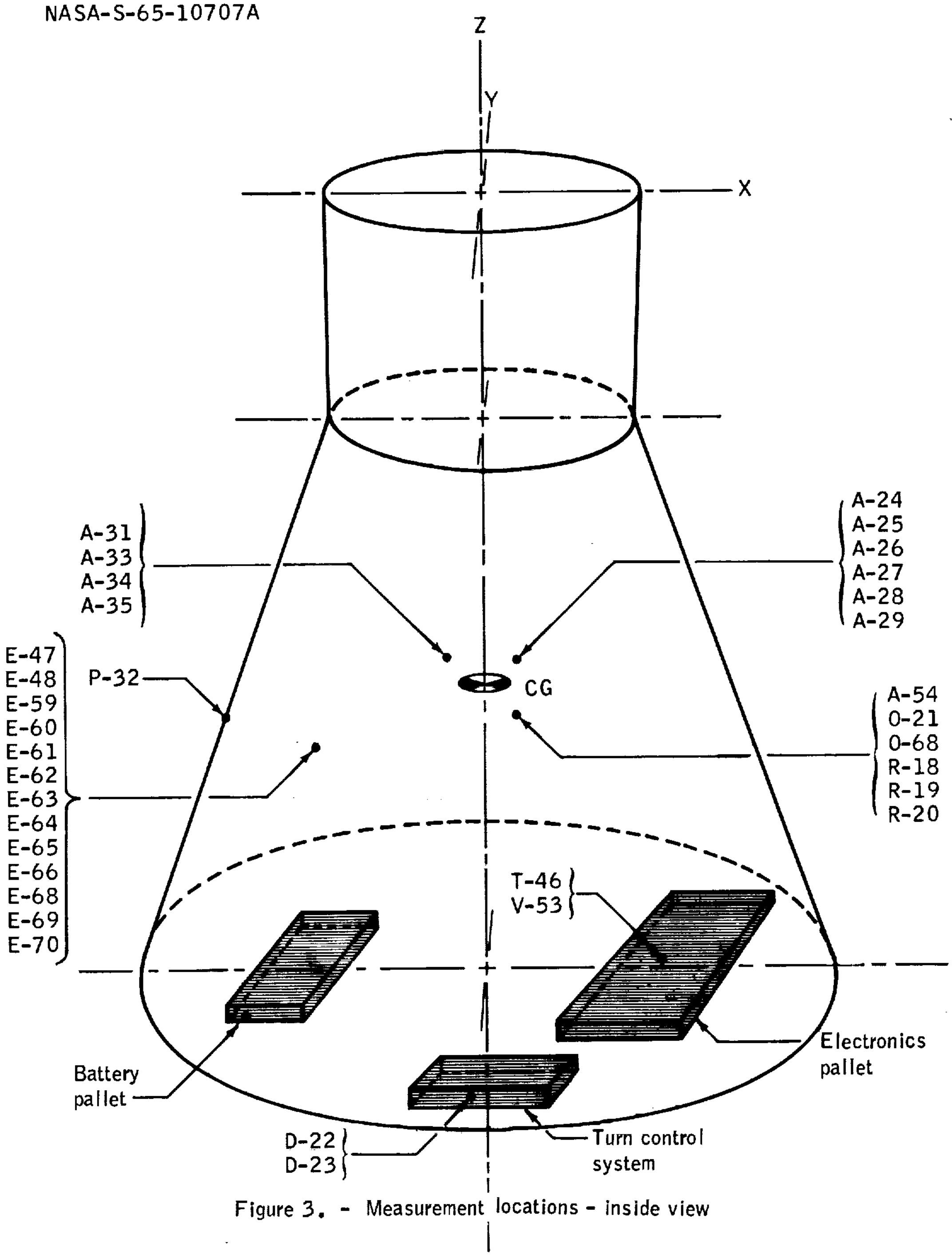

Figure 3. - Measurement locations - inside view

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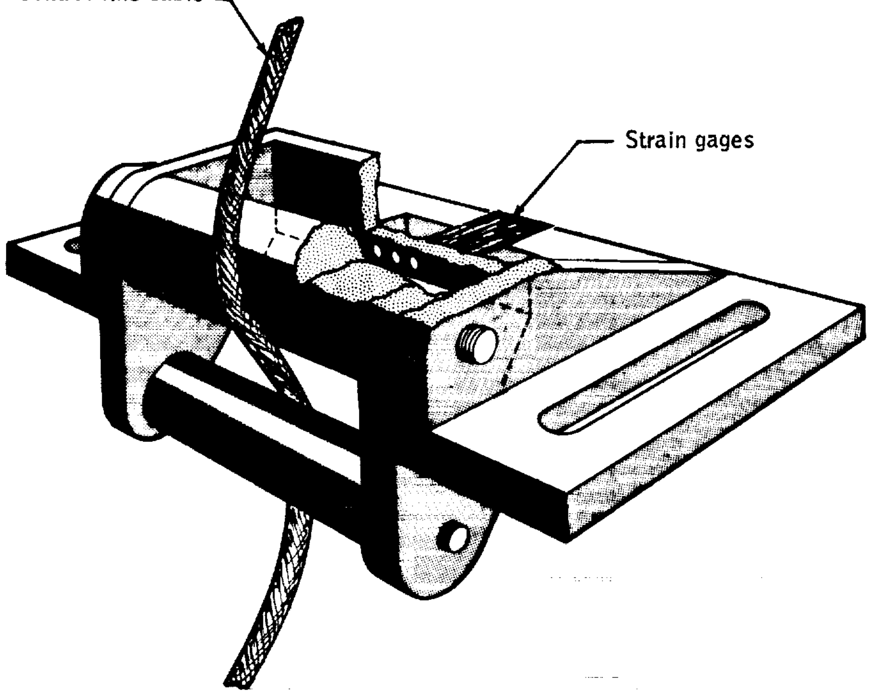

Figure 4. - Control line transducer.

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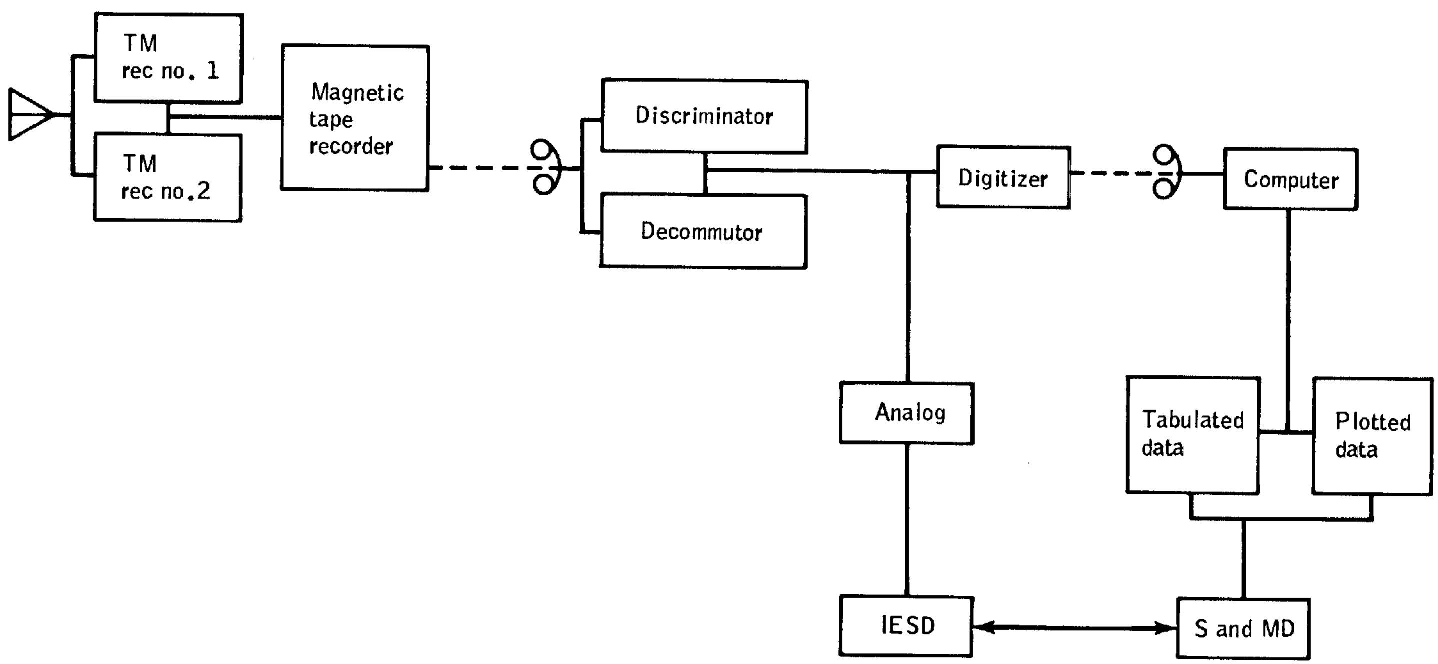

Figure 5. - Data flow chart.

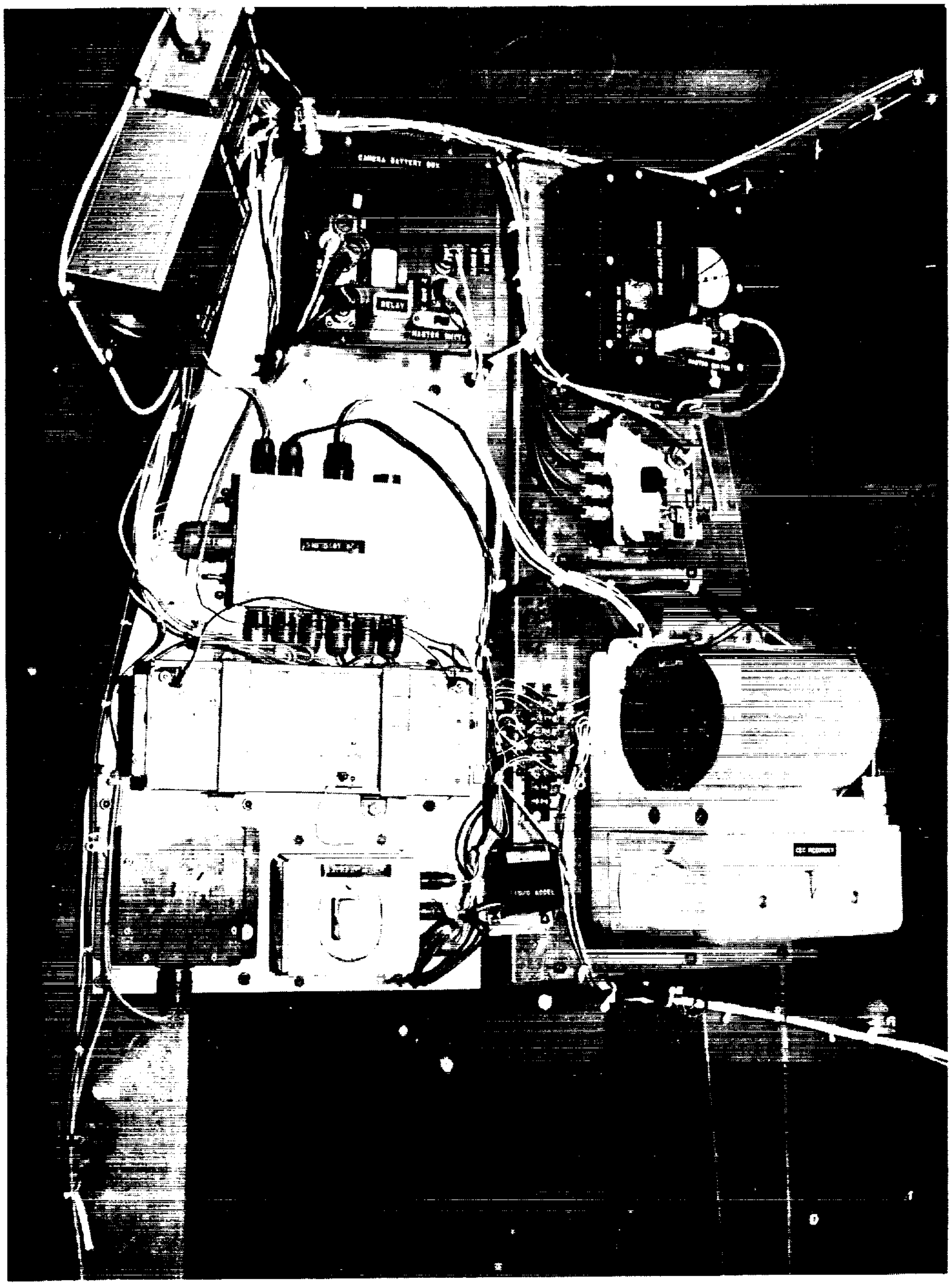

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Figure 6.- Instrumentation for first deployment test.

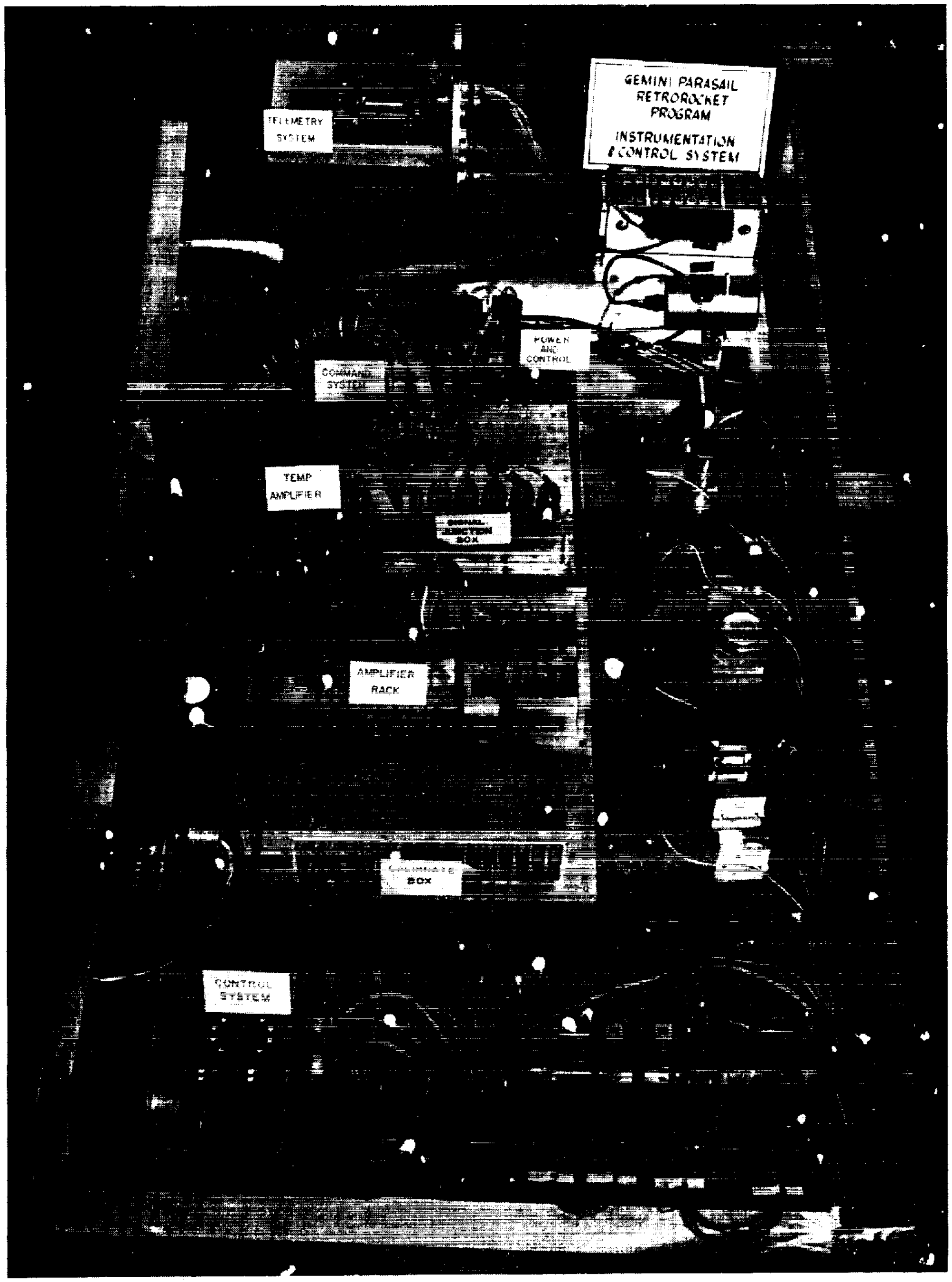

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Figure 7.- Instrumentation breadboard, airdrops 2 through 5.

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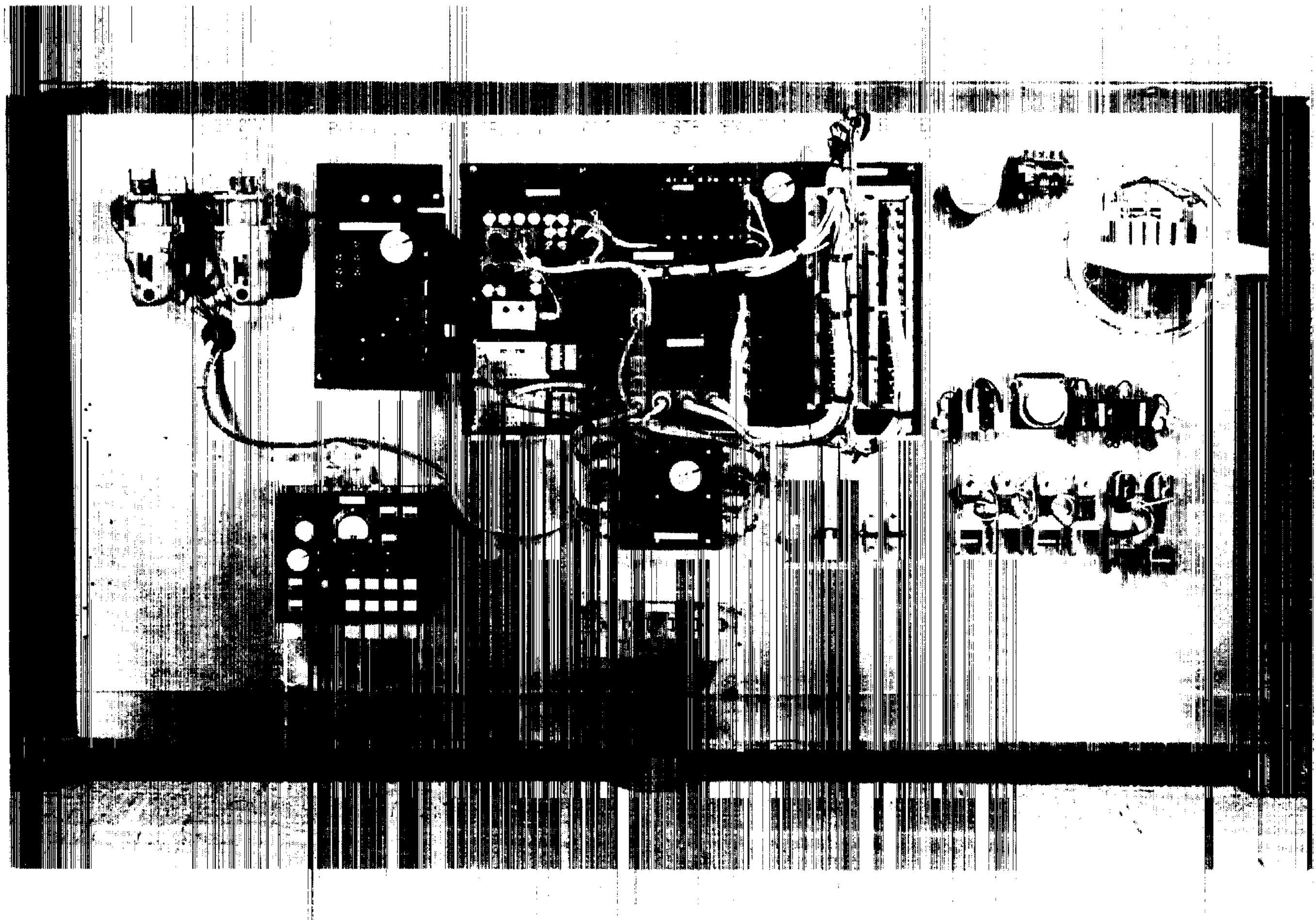

Figure 8.- Instrumentation breadboard, airdrops 6 through 12.

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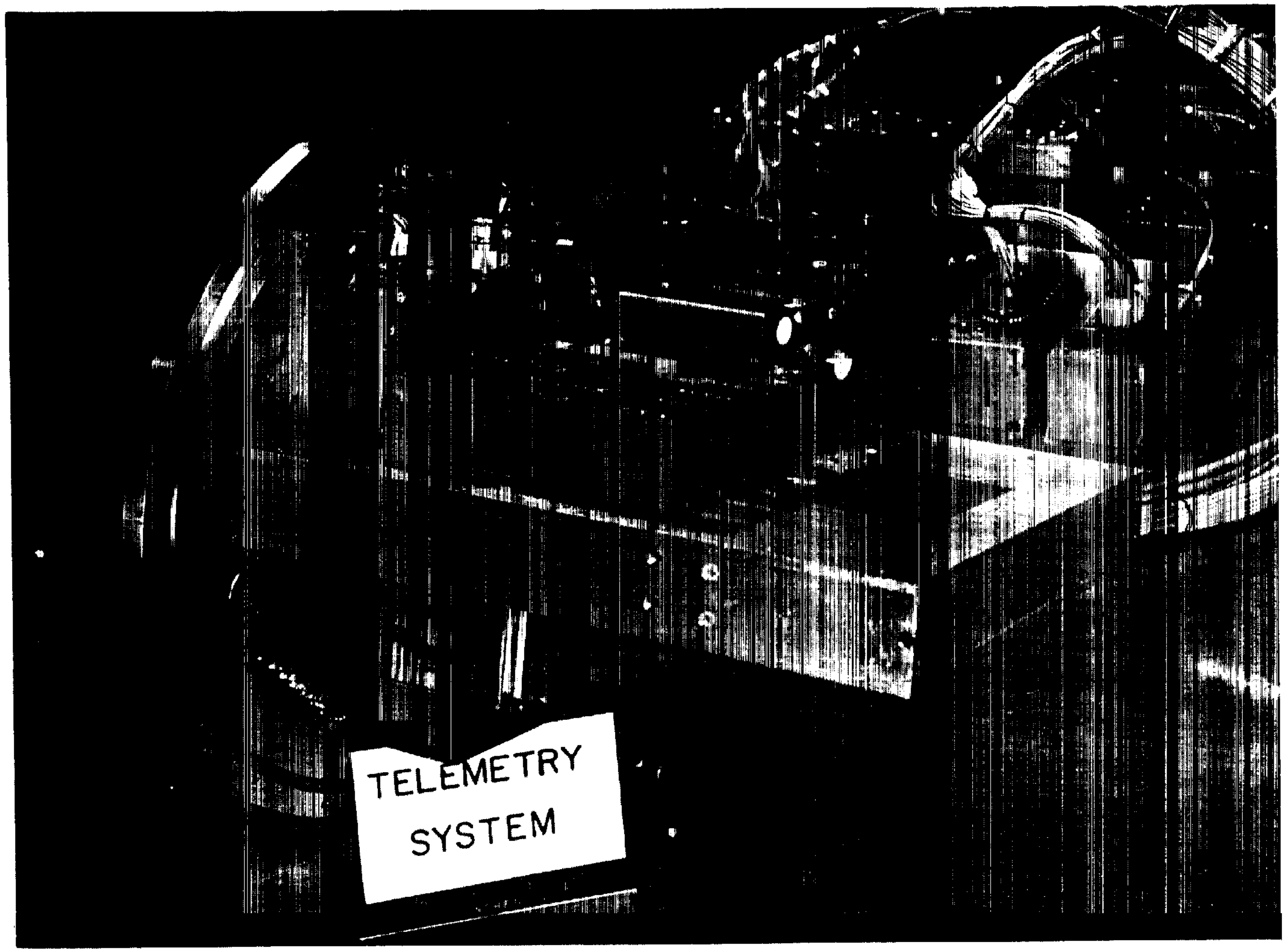

Figure 9.- Telemetry system.

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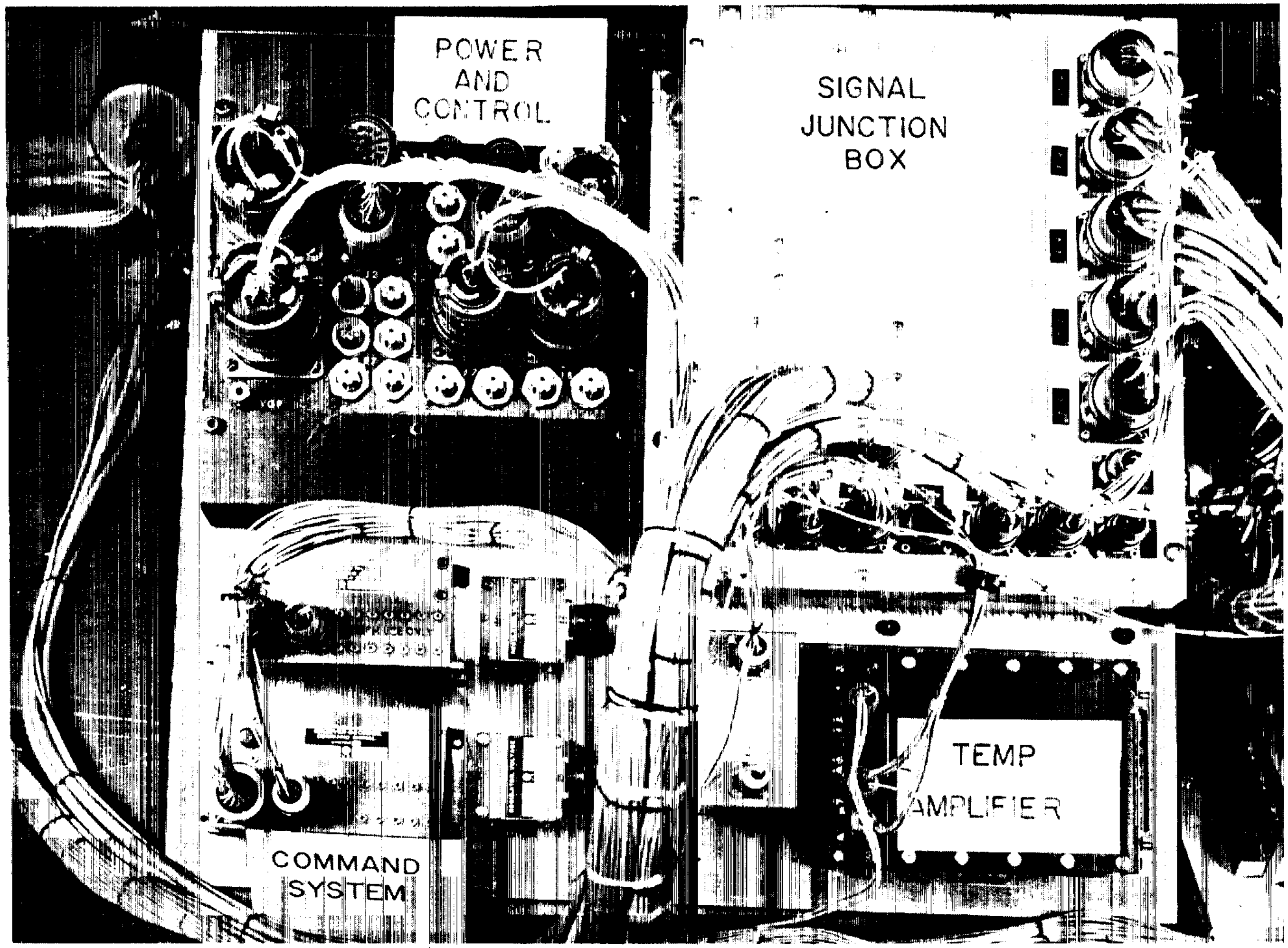

Figure 10.- Instrumentation and electronic systems.

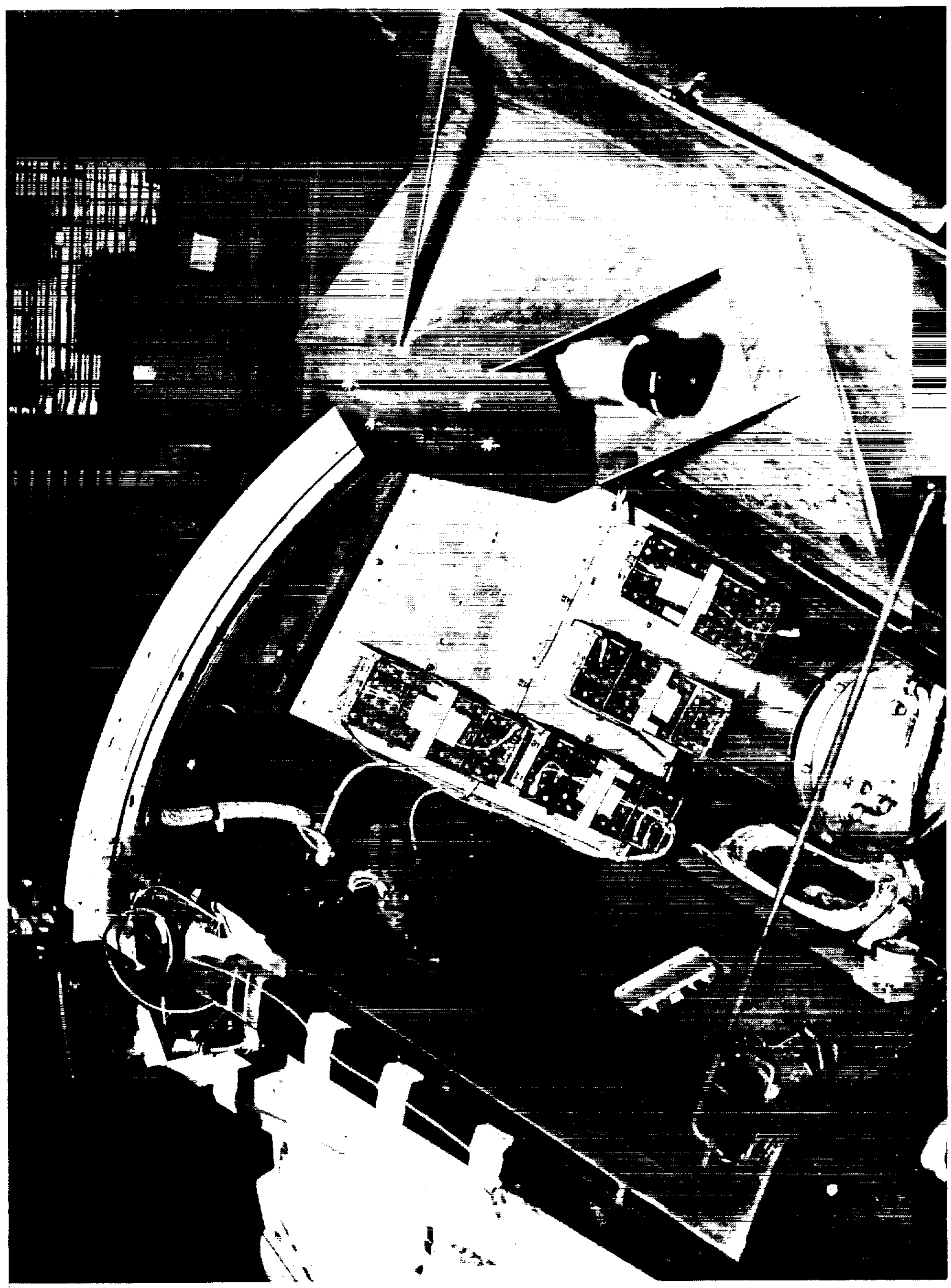

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Figure 11.- Battery pallet.

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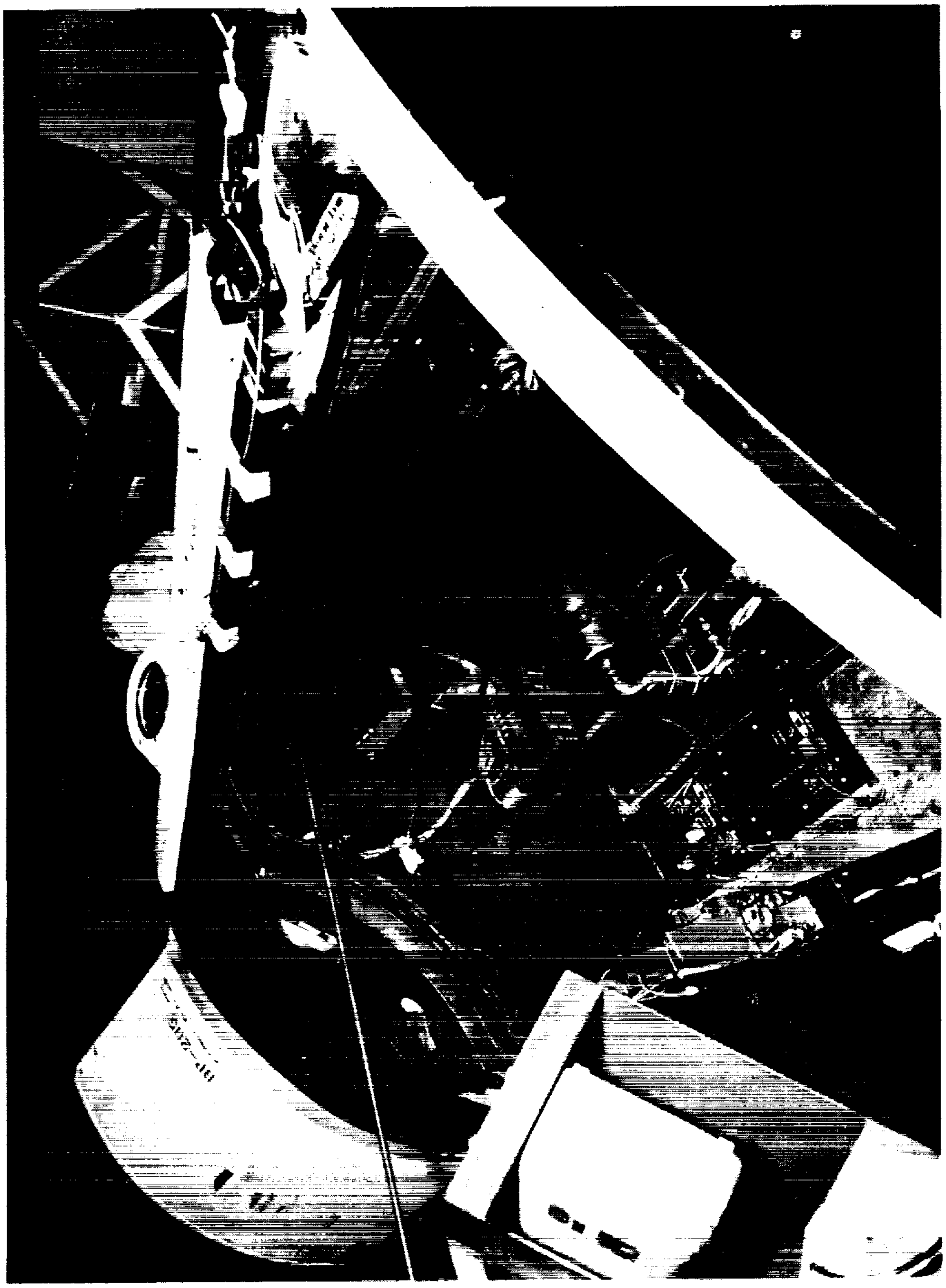

Figure 12.- Instruments at the center of gravity.

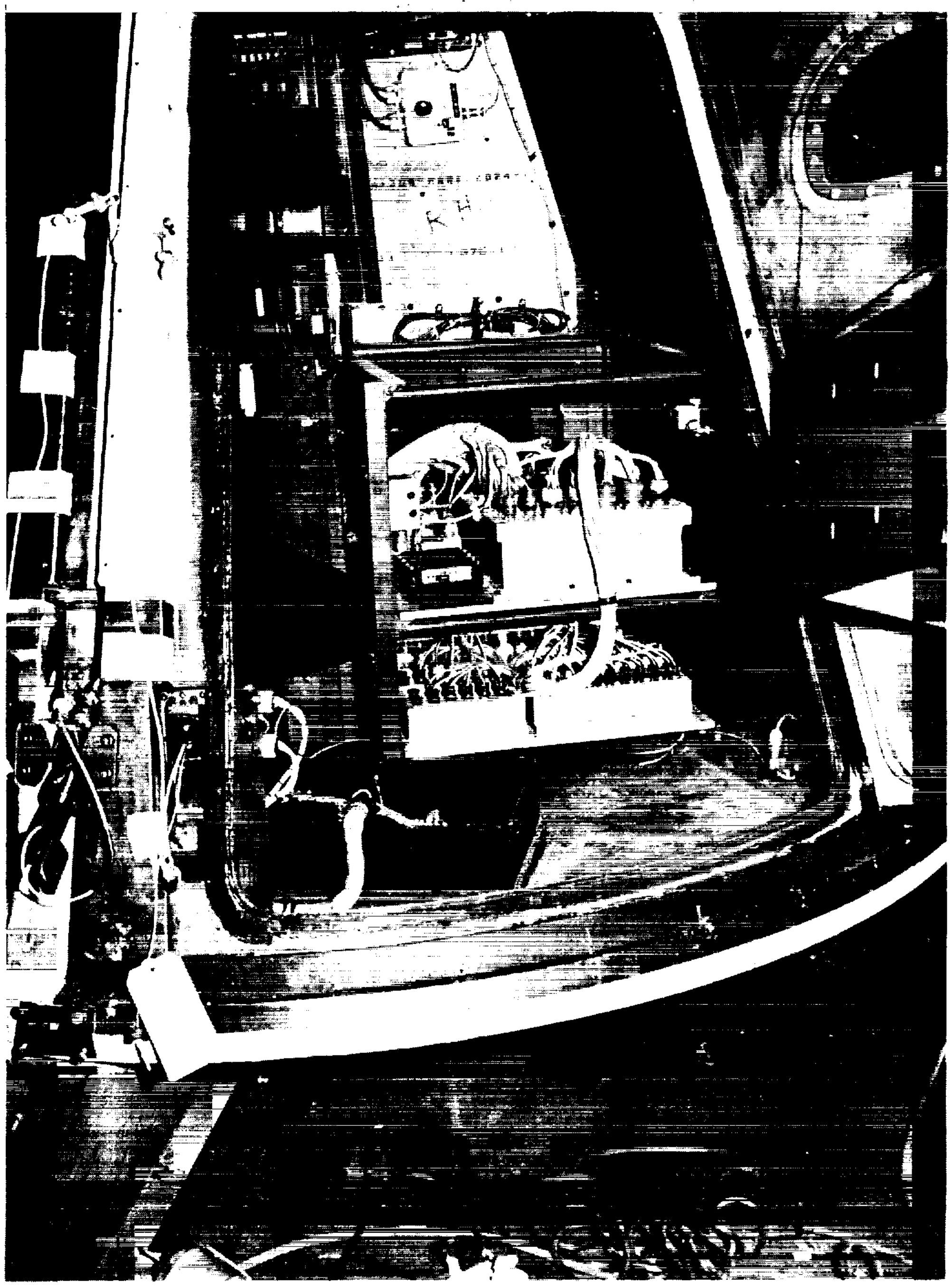

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Figure 13.- Instrumentation pallet BP-205.

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S-64-34165

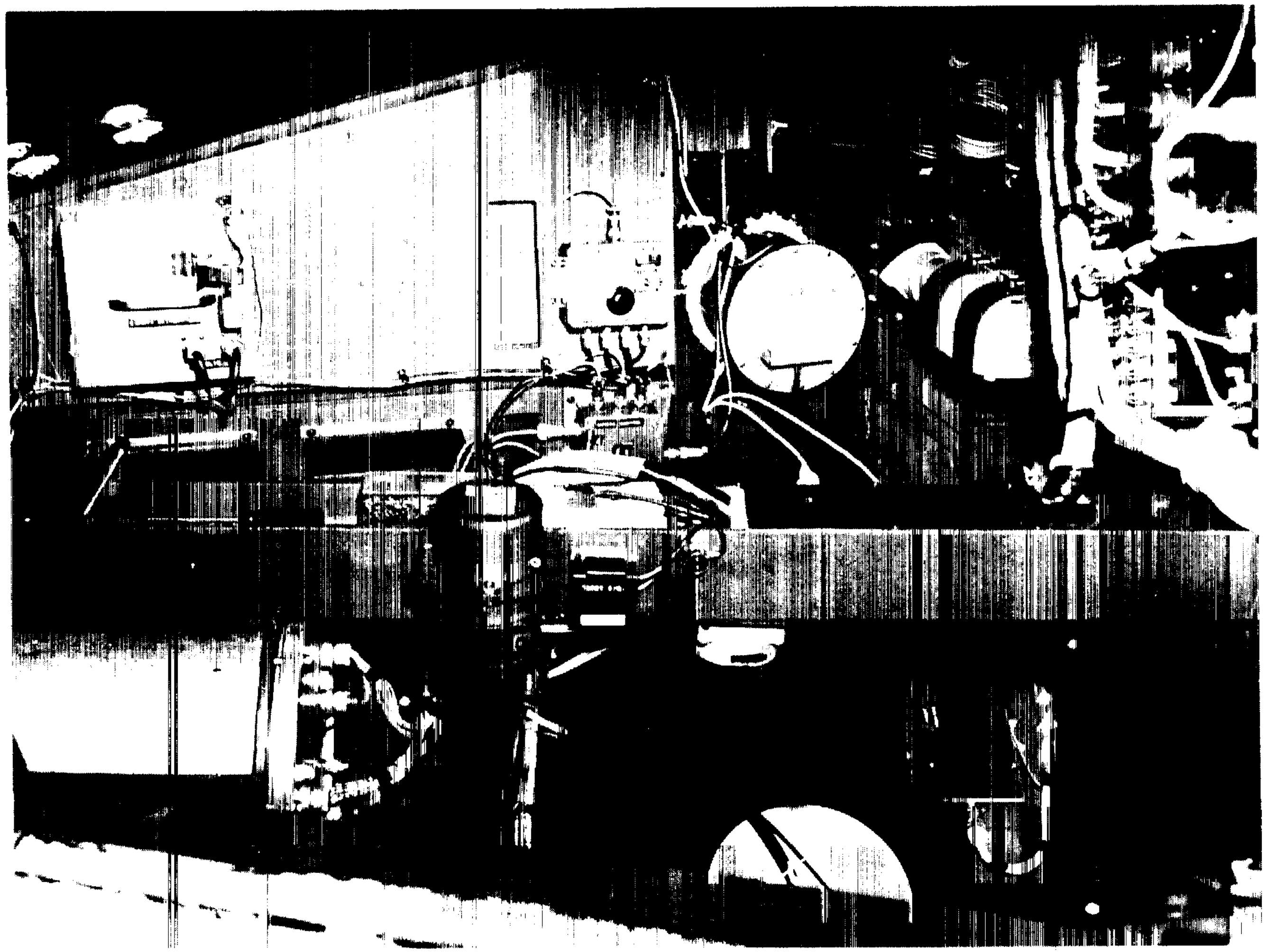

Figure 14.- Instrument systems BP-206.

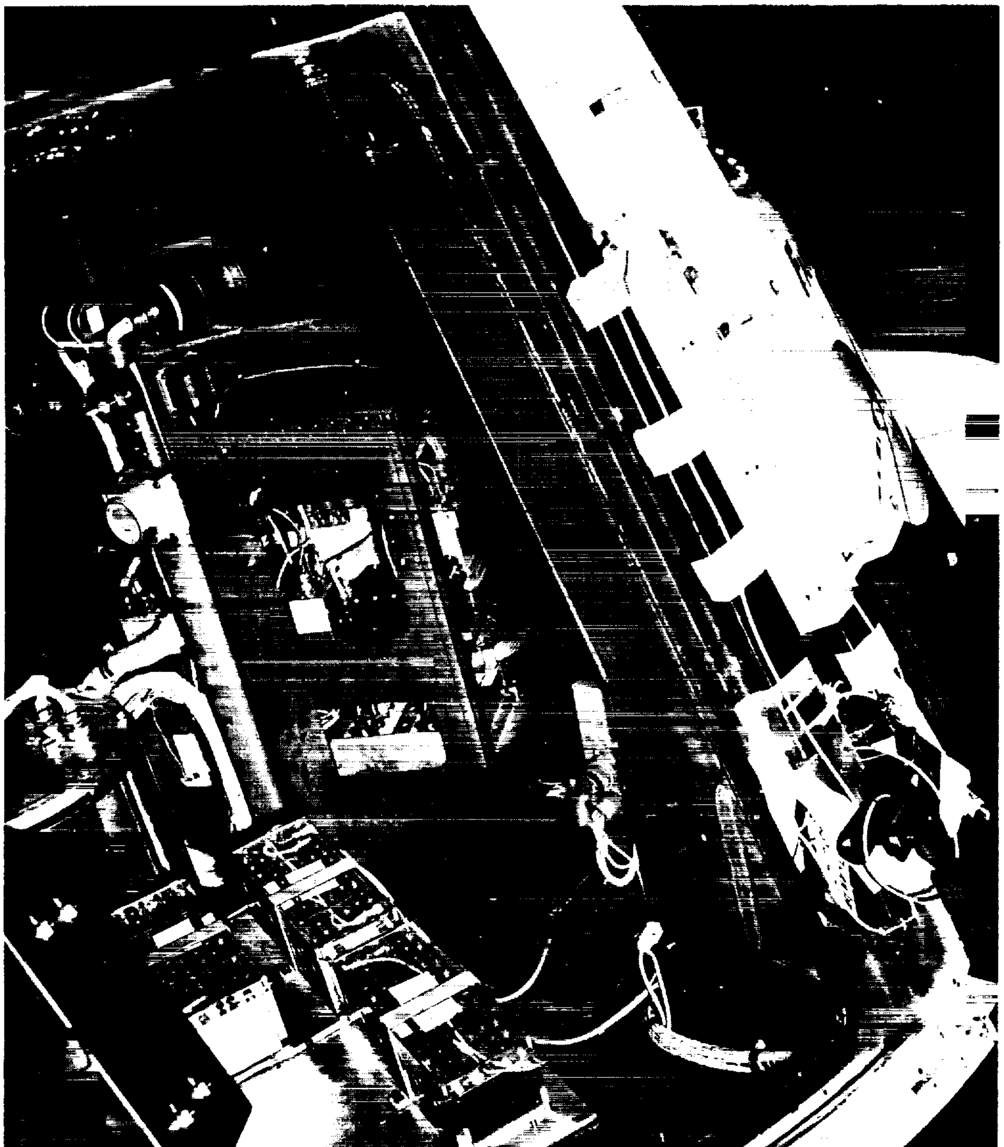

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Figure 15.- Complete instrumentation system BP-205.

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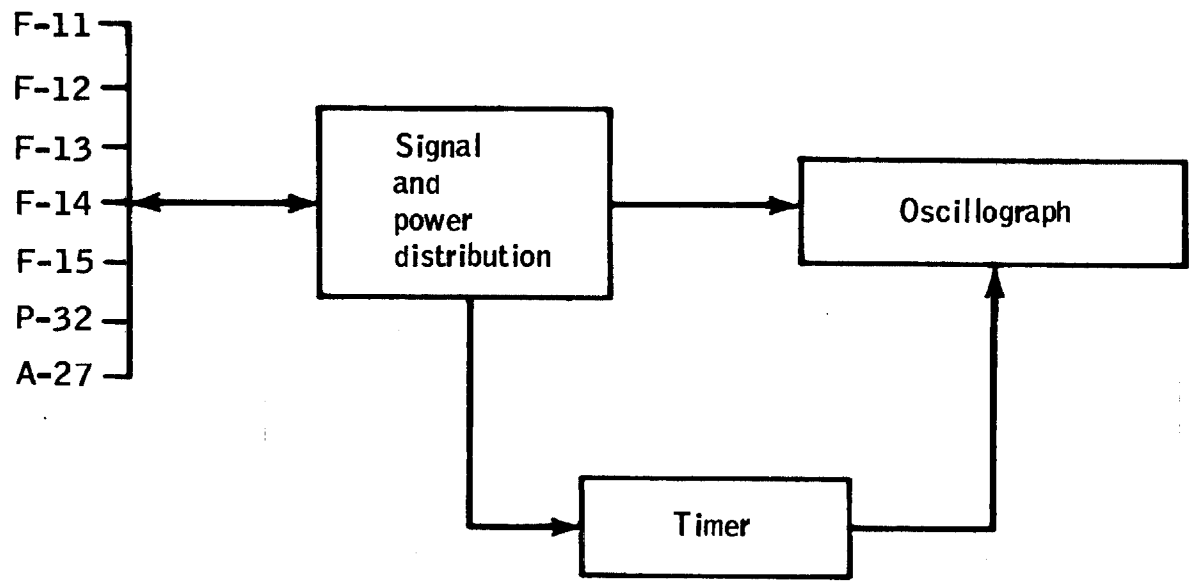

Figure 16. - Instrumentation and electronic systems for air drop no. 1.

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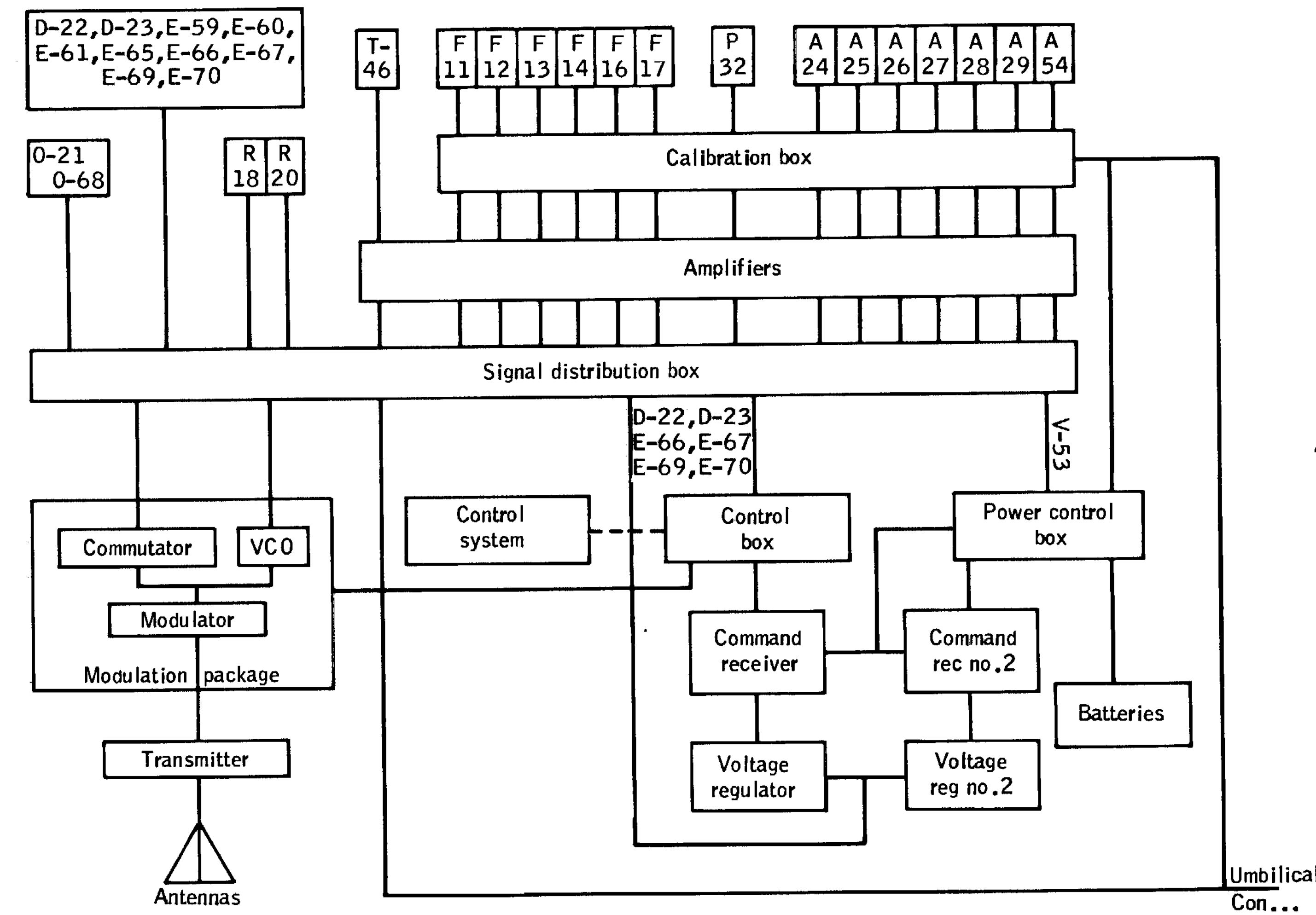

Figure 17. - Instrumentation and electronic systems for air drops 2 through 5.

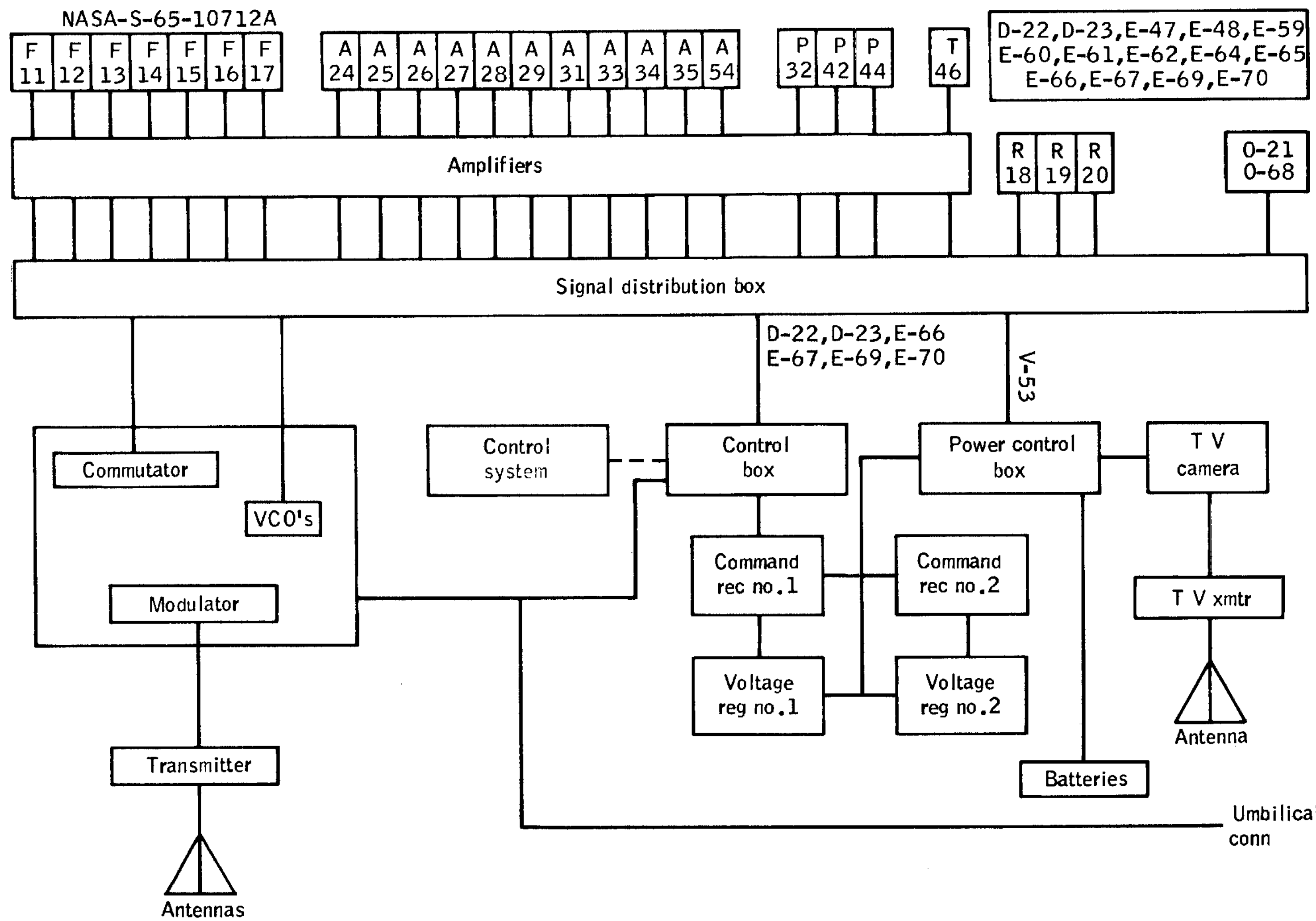

Figure 18. - Instrumentation and electronic systems for air drops 6 through 12.